High-Solids Wood Furniture Coatings Case Studies

Midwest Research Institute, in cooperative agreement with the Air Pollution Prevention and Control Division of the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory, conducted a study to identify wood furniture manufacturing facilities that had converted to low-volatile organic compound (VOC)/hazardous air pollutant (HAP) wood furniture coatings and develop case studies for those facilities. The primary goals of the project were to demonstrate that low-VOC/HAP coatings can be used successfully by some wood furniture manufacturing facilities and to provide a resource to assist other wood furniture manufacturing facilities in converting to low-VOC/HAP coatings. This document is a compilation of the high-solids coatings case studies developed under the cooperative agreement.

The table below presents the case studies completed for wood furniture manufacturing facilities using high-solids/low-VOC/HAP coatings. The following areas were examined in the case studies:

- The types of products the facility manufactures;
- The types of low-VOC/HAP coatings the facility is using;
- Problems encountered in converting to low-VOC/HAP coatings;
- Equipment changes that were required;
- The costs and cost savings associated with the conversion process, including capital costs, research and development costs, operating costs, and material/labor savings;
- Emissions and waste reductions achieved;
- Advantages/disadvantages of the low-VOC/HAP coatings; and
- Customer feedback on products finished with the low-VOC/HAP coatings.

Facility	Product	Coating
Bentwood Furniture Grants Pass, OR	Residential furniture	High-solids, low-VOC/HAP sealer, topcoat
Crystal Cabinet Works Princeton, MN	Cabinets	High-solids sealer, topcoat Waterborne adhesive
Design Fabricators Lafayette, CO	Store fixtures, conference tables, entertainment-type pieces	High-solids sealer, topcoat, low/no-HAP coatings
Ethan Allen Beecher Falls, VT	Residential furniture	High-solids sealer, topcoat
Saloom Winchendon, MA	Residential furniture	Waterborne adhesives High-solids sealer, topcoat

Facility	Product	Coating
Westwood Custom Cabinetry Salem, OR	Cabinets	High-solids, low-VOC/HAP sealer, topcoat

Case Study No. 6   High-Solids Coatings
Bentwood Furniture
Grants Pass, OR

Background
Bentwood Furniture is an independent furniture manufacturer that sells nationwide and in Canada, with annual sales of about $9 million. They manufacture dining room, bedroom, and home theater furniture. The facility runs two 8-hour shifts, Monday through Friday, and occasionally operates on Saturdays for shipping and rework. Bentwood has 89 employees, 11 of whom are finishing employees. They switched to high-solids, low-HAP coatings in 1997 to reduce emissions and ensure compliance with the Wood Furniture NESHAP. They plan to switch to waterborne coatings sometime in the future.

Manufacturing and Coating Operations
Bentwood manufactures all their furniture on-site (only the chair cushions are assembled off-site). Raw lumber (oak, cherry, and myrtle wood) is received at the facility and is milled into various furniture components. The wood chips and sawdust from the milling operations are sold to a local firm. The furniture may be assembled before (e.g., a chair) or after (e.g., an entertainment center) it is coated.

Bentwood has one coating line that is approximately 100 feet long and circular in shape. The product is suspended from hooks and travels around the line 3 times -- once each for application of stain, sealer, and topcoat. The pieces are placed on the line at intervals of approximately 1 minute to allow adequate time for the spray operator to coat each piece. On the first pass around the line, the stain is hand wiped onto the piece; Bentwood has 10 to 12 different stain colors that they can apply to different products. The sealer is applied using an HVLP or airless spray gun. The piece is sanded and then the topcoat (usually low-gloss) is applied using an HVLP or airless spray gun. The line speed varies by product, but is typically 8 to 12 feet per minute (one pass around the line takes about 12½ minutes).

There are no drying ovens on the finishing line. To ensure each piece is fully dried before packaging, operators let the finished product sit for about half an hour in an area at the end of the finishing line before stacking or packaging. Products with finishing defects are sanded and recoated (no solvent is used for rework). Products with defects in the wood are disassembled, and the defective component is replaced.

Coatings are received in 55-gallon drums from two coating suppliers. Bentwood uses U.S. Cellulose stains and Lilly sealers and topcoats. Enough coating for about one week of operation is received with each shipment. The empty drums are returned to the coating suppliers for reuse. In the future, Bentwood plans to start using large totes in containment areas.

Cleaning Operations
Bentwood currently uses acetone to clean their spray guns. The solvent is sprayed into the spray booth. Cleaning rags are sent off-site to be laundered and are reused. The facility previously used paper spray booth filters and changed them twice per week. They now use fiberglass-based filters which last twice as long and therefore create less solid waste.

Conversion to High-Solids Coatings
Bentwood switched their coatings in 1997. They reduced both VOC and HAP emissions by going to a high-solids, low-HAP sealer and topcoat. They also reduced the VOC and HAP content of some stains. A conversion to waterborne coatings is planned in the next few years. When Bentwood makes the switch, the plant will be expanded and new spray equipment and drying ovens will be purchased. They plan to convert to a finishing line that uses tow carts under a hanging line and will stay with their current coating suppliers.

Facility personnel stated that the conversion to the high-solids, low-HAP sealers and topcoats was smooth. No additional operator training due to the coatings change was necessary. Their coating suppliers had worked with similar facilities to convert their coating systems, so the conversion process at Bentwood was relatively smooth. The coating suppliers brought small amounts of each coating for the facility to test, and the coatings were reformulated only once due to excessive dry time. The change to HVLP guns for all staining and some sealer and topcoat application did require some additional operator training.

The new coatings do contain some acetone. If the temperature in the finishing room gets too high, it sometimes is necessary to add more acetone to the coating to prevent too much solvent from evaporating before the coating reaches the piece. However, since acetone is neither a VOC nor a HAP, this thinning does not contribute to the facility's overall VOC or HAP emissions.

Costs
The switch to low-HAP coatings has reduced their permit cost and the paperwork required by their permit because their new coatings have a higher solids content and they use HVLP guns for most of their coating application. This has created a cost savings for the company because the coating cost per gallon remained about the same overall.

Emissions
Bentwood stated that they were emitting over 10 tons each of nine different HAPs with their old system, and now emit about 20 tons of total HAPs, which consist largely of glycol ethers and xylene. Bentwood uses two types of sealer and two types of topcoat. The material safety data sheet (MSDS) showed that these coatings range in solids content from 20 to 32 percent and have HAP contents of 0.16 to 0.38 pound of HAP per pound solids.

Customer Feedback

Facility personnel stated that their customers like the products finished with the new coatings. They particularly like the depth of the new stains. There has been no change in the number of complaints received. Bentwood is satisfied with their new finishing system and the reductions in cost and labor it has given them.

Case Study No. 8 Low-VOC/HAP Coatings and Waterborne Adhesives
Crystal Cabinet Works, Inc.
Princeton, MN

Background

Crystal Cabinet Works (Crystal) was founded in 1947 and produces high-quality custom cabinetry for kitchen, bath, or home theater use. There are two facilities located in Princeton, Minnesota: a small component manufacturing facility and a larger facility that machines, builds, finishes, and assembles cabinetry. Total weekly production averages around 2,300 cabinets a week, of which 90 to 95 percent are coated. In mid-1995, Crystal began to reformulate their coatings and adhesives as part of an overall pollution prevention effort.

Manufacturing and Coating Operations

Crystal's products consist of solid wood (birch, red oak, hickory, cherry, pine, maple, or heartwood maple) or engineered wood products (particleboard, MDF, or plywood). One facility mills the solid lumber into moldings, linear material for door stiles and rails, and some door panels. These components are transported to the other larger facility, combined with other components that are milled at that facility, then shaped, finished, and assembled to produce the final product.

The cabinet components first are cut, shaped, and sanded. The type of shaping and sanding machines depends on the style of the desired final product. Waste solid wood door panels are collected, returned to the milling plant, taken apart, glued together into new door panels, then planed to a half-inch thickness for use as thinner panel inserts. This practice allows Crystal to reuse defective door panels and reduce the amount of wood waste generated. The wood waste that cannot be reused is chipped and sold as animal bedding. After shaping and sanding, the parts are taken to either the assembly or finishing areas. Products are finished before assembly, after assembly, or a combination of the two.

The first step in the finishing department is to clean the product with an automated brush/vacuum machine to remove all sanding dust or particles. Crystal has two finishing lines: an automated flat line and a manual cart line. The manual line is used to finish assembled, or partially assembled, three-dimensional products that cannot be accommodated by the automated flatline system. On the manual line, the parts are placed on tow carts that move automatically through the spray booths. The coatings are applied manually with air-assisted airless guns, which have a manufacturer-rated transfer efficiency of 75 to 80 percent.

First, a stain is applied and hand wiped in the stain booth. Next, a sealer or primer is applied, then dried in an oven and hand sanded. This sealer or primer step is then repeated, passing through the same oven. The final coating is either a clear topcoat or enamel and is applied in the topcoat booth and dried in the second oven. When the finishing process is complete, the product is unloaded and prepared for assembly.

The spray booths on the automated flat line have several features to help increase efficiency and prevent pollution. First of all, electronic eyes minimize overspray and wasted finishing material by triggering the guns only when the eye senses product as it travels through the spray booth. The spray guns themselves are air-assisted airless guns, again with a manufacturer-rated transfer efficiency of 75 to 80 percent.

In the first automated spray booth on the flat line, the product receives a stain, primer, or glaze. Stains or glazes are hand wiped. All coatings applied on the flat line are dried in one of two stack ovens, with a required residence time of approximately 45 minutes to dry the coating. The time required varies depending on the type of coating applied. For primer coats, a halogen IR oven is used. The IR oven has a cure time of approximately 2½ minutes; the exact time varies by coating. The proper cure is achieved by varying the line speed through the oven, the air flow, and the temperature of the oven. The process then is repeated for the other side of the panel.

In the second spray booth on the automated line, the product receives a coat of sealer and is dried in a conventional stack oven. Both sides of the piece are coated and dried. The product is sanded, and a second coat of sealer is applied to both sides. The third line is used to apply the topcoat. The product is dried in a stack oven, and the opposite side of the piece receives a topcoat and is dried.

Most wood coatings and solvents are received in 55-gallon drums and 5-gallon buckets. Sealer and topcoat are shipped by dual tanker trucks and stored in bulk storage tanks. As needed, these coatings are dispensed into 55-gallon drums. Some used drums collect hazardous waste (cleaning solvent or waste coating) and the rest are recycled or sent back to the manufacturer.

Gluing Operations

Crystal also replaced a solvent-borne contact adhesive with a waterborne alternative. Prior to 1995, the contact adhesive used at Crystal to adhere laminates to engineered wood contained methylene chloride, a suspect carcinogen and known HAP. This system was replaced by a waterborne neoprene-rubber contact adhesive that is applied by HVLP guns and dried by IR lamps. The final waterborne system provides better adhesion than the original glue and greater coverage per drum, reducing overall costs. The environmental and health benefits are even greater, although not as easily quantified.

Cleaning Operations

Due to the high volume of custom work, color changes are frequent at Crystal. Each time the color is changed, the lines must be flushed with cleaning solvent to remove all of the previous color. This practice can produce a high volume of solvent waste, the majority of which is acetone, toluene, and methyl ethyl ketone (MEK). However, in

March of 1999, Crystal installed an automatic color changer on its flat line in order to reduce amount of flushing solvent and time required to switch colors.

In addition to cleaning the lines, the spray equipment and conveyors also must be cleaned. To reduce the amount of cleaning solvent used, the spray booths are cleaned with dry methods, such as chipping off dried coating that has accumulated on the walls of the spray booths.

Conversion to Low-VOC/HAP Coatings and Waterborne Adhesives

The switch to low-VOC/HAP finishes was relatively easy for Crystal Cabinet Works. Because high-solids coatings already were in use, equipment changes were unnecessary and adjustments to the sealer and topcoat were minimal. The sealer and topcoat already were high-solids catalyzed coatings and required only minor adjustments to comply with any regulatory requirements. The stains required more reformulation however, and color matching was a problem. Each color was tested two to five times before a suitable finish was established, a process that required 18 months. Once the change was made, the quality of the finish was equivalent to that of the original finish and the change was generally unnoticed by customers. Increased drying time also was an issue, but was resolved with the addition of IR lamps to the coating line to replace conventional ovens.

The change in glues was more difficult, expensive, and labor-intensive than the coatings reformulation project. However, methylene chloride's status as both a suspect carcinogen and HAP provided several incentives for changing the glue: reduced environmental impacts, improved employee health, and compliance with increasingly stringent EPA and OSHA regulations. Methylene chloride emissions from gluing operations were substantial, at 24 tons per year for both facilities combined. Although it would have been possible to switch to another solvent-borne adhesive, Crystal recognized the opportunity to change to a high quality waterborne glue, virtually eliminating the environmental and health hazards.

Because of previous experience with glue failure, Crystal spent extra time and resources to ensure the best combination of technology was utilized. Over a period of 18 months, 16 glues were tested for several characteristics. The primary characteristic sought for this new glue was bond strength: in order to maintain product quality, it had to be equivalent to (or better than) the methylene chloride-based glue. The workability of the glue also was important; it had to both maximize tackiness and minimize dry time. Each glue was tested under different process variables to find the most effective application method. These process variables included: drying method (air or IR), application method (spraying or roll coating), and setting/bonding pressure (J-roll or pinch-roll). A waterborne neoprene-rubber contact adhesive was chosen, applied by HVLP guns, and dried by IR lamps. This system provides not only a safer glue with virtually no HAP or VOC emissions, but also one with greater bond strength than the glue it replaced.

Costs
Costs to reformulate the finishes were minimal because the sealer and topcoat required only very minor changes. However, the stains required several reformulations to achieve the desired appearance. This reformulation took approximately 18 months of research and development to accomplish. No new equipment was required because high-efficiency guns already were in use.

The methylene chloride-based glue was not only an environmental hazard, but dangerous to the health of the employees as well. Therefore, Crystal felt they needed to provide a better working environment for their employees. The equipment costs, including new HVLP guns and IR lamps, were approximately $110,000. In addition, labor costs from research and development, although not measured, were substantial because three full-time employees worked on the project for 18 months. However, the waterborne glue is only marginally more expensive per gallon ($16.50 compared to $15.00 for the methylene chloride-based glue) while the coverage is more than twice that of the old glue. In 5 months, 15 drums of the old glue were used; during an equivalent period of time, only 7 drums of the new waterborne glue are used. This increase in coverage has halved the glue supply costs.

Emissions
According to Crystal, the reformulation of the finishing materials caused a significant decrease in their annual VOC emissions. In 1994, 472 tons of VOCs were emitted. By 1997, this number had been reduced to 152 tons of VOCs, representing a decrease of over 67 percent. The HAP emissions also decreased dramatically; Crystal is subject to the Wood Furniture NESHAP and was in compliance by late 1996. The change to a waterborne glue provided most of the HAP decrease; the previous glue was 88 percent methylene chloride. The new waterborne glue also has a low VOC content, only 0.10 pound VOC per gallon. Facility personnel stated that when Crystal converted to the waterborne glue, their toxic chemical use was reduced by 16 tons per year.

Case Study No. 9   High-Solids Coatings
Design Fabricators
Lafayette, CO

Background

Design Fabricators produces custom store fixtures and entertainment/ornamental items. Most of their production consists of coated wood products made from sheet goods; 60 to 70 percent of the coatings are clear sealers or topcoats. A small percentage of the coatings, five to ten percent of total sales, are used to coat metal or fiberglass. The plant operates five days a week with two shifts. The number of hours worked and number of employees vary seasonally, but averages close to 200 employees on two 8-hour shifts. Approximately 25 of those employees are in the finishing department.

In October 1994, Design Fabricators moved into their current location. Prior to the move, the local community raised concerns over emissions and the odor of the solvent-borne coatings. The company was interested in pursuing new finishing techniques and lowering emissions, but they found that information about low-VOC/HAP coatings was not readily available. By November 1995, alternative coatings were under serious consideration and were being tested for quality, durability, and cost effectiveness. The new coating system was fully implemented in early 1996.

Manufacturing and Coating Operations

Most commonly, raw material is purchased in sheet form. The sheet goods are then cut to size and edged with laminate or wood tape if necessary. Both processes are automated. Some solid woods, which need to be ripped, planed, and milled, also are used for products such as tables and benches.

The components are then taken directly to either the assembly area or the finishing department. Depending on the product, it may be finished before or after assembly. In the assembly area, there are specified areas for different jobs. Products are assembled and sanded by hand. In the finishing department, the product is taken into one of the two spray booths and placed on hangers (the larger items are rolled in on trolleys). The hangers are moved manually throughout the finishing area, with the operators taking care not to touch the product until the finish is cured. Most of the coatings are applied using air-assisted airless guns, although a small number of custom jobs require conventional spray guns. The coatings are pumped from 55-gallon drums in the paint kitchen directly to the spray guns in the booths. The only exception is the catalyzed conversion varnish, which is mixed in 5-gallon batches and put into smaller pumps located in the spray booth. The stain is applied first and is hand wiped for some products. The product then is sprayed with a sealer and sanded. Finally, a topcoat is applied and the product is allowed to air dry. After the finish has cured, the product is packaged and shipped to the customer.

Conversion to High-Solids, Low-HAP Finishes

Design Fabricators tested several different coatings and suppliers before settling on their current finishing system. First, waterborne coatings were used on some of the smaller orders, but they caused several problems. The biggest problem was grain raise. When a waterborne product is applied to wood, especially the softer species, the grain of the wood absorbs the water and stands up, or raises. Grain raise results in a rougher finish that lacks the smoothness that is typically achieved using solvent-borne coatings. In an attempt to rectify this problem and smooth the grain, additional sanding was required. However, the operators often sanded through the seal coat. This would cause the grain to raise again when the topcoat was applied because the wood was re-exposed to a waterborne coating.

Another problem encountered with the waterborne coatings was drying time. To prevent the parts from sticking together, waterborne products generally require a much longer drying time before they can be stacked or shipped. This problem can be helped by adding drying ovens to speed the curing process. However, additional equipment would not only be expensive, but would also require more space than the facility can devote to finishing. A third problem Design Fabricators encountered with their waterborne coatings was a softer finish that was not as durable. Because of these difficulties, waterborne coatings were not chosen for the new system.

Design Fabricators next considered UV-cured coatings. Ultraviolet-cured coatings have the low-VOC/HAP advantage of waterborne products while producing a durable, high-quality finish. Grain raise is avoided because UV-cured coatings can have up to 100 percent solids and no water. The very-high solids content prevents the VOC and HAP emissions associated with traditional solvent-borne coatings. The curing time also is very short, only a few seconds. However, UV-cured coatings are most feasible for flatline finishing, making UV finishing impractical for Design Fabricators because of the wide variety of shaped pieces that they finish.

The final coating system tested by Design Fabricators included a high-solids catalyzed conversion varnish and low-HAP sealers and stains. The VOC and HAP content of these coatings is still low due to the high solids content, and the problems experienced with the waterborne coatings tested by the facility were avoided because the coating is acetone based. The acetone-based coatings are applied using spray guns, allowing easy finishing of shaped pieces. The main problem with acetone-based finishes is that they tend to dry too quickly. However, drying time may be adjusted by adding other solvents. Acetone also is very flammable, and fire risks are an important issue. However, because of the high-quality finish and compatibility with the existing finishing line, the high-solids, low-VOC/HAP system was selected. The new topcoat has around 40 percent solids, where the old topcoat had about 18 percent solids. Gradually, the old precatalyzed topcoats are being phased out and replaced with the high-solids catalyzed conversion varnishes. Catalyzed finishes have a higher solids content and result in a more durable finish. The harder finish is achieved because the coating is not only dried, but is cured by a polymerization reaction controlled by the amount of catalyst in the coating.

The transition to high-solids coatings was fairly smooth for Design Fabricators. There was a learning-curve period of six to eight months during which the operators became familiar with the new coatings and different coatings combinations were tried to achieve the best finish possible. Because the new system is compatible with the original solvent-borne system, the operators were able to make the minor adjustment rapidly. The coating process did not undergo much change when the coatings were changed. The new coatings are applied manually using spray guns, as were the old coatings.

Costs

Although the new finishes cost more per gallon ($18 per gallon versus $11 per gallon for the topcoat), the overall costs are approximately the same because of the higher coverage associated with high-solids coatings. Design Fabricators feels any slight increase in cost is worthwhile; the high-solids finishes are not only lower-emitting, they also produce a quality finish equal to, if not better than, the original solvent-borne system.

Emissions

According to data provided by the facility, the switch to high-solids coatings resulted in a considerable decrease in the annual VOC and HAP emissions for the plant. The coatings changes also served to address the local community's concerns about their emissions. The new coatings typically average around 1 pound of VOC per pound of solids. In 1995, before beginning the switch to the lower-emitting coatings, around 44 tons of VOCs were emitted. After the complete conversion to the new system, only about 36 tons of VOCs were emitted over a 12-month period. Although the difference seems small, the company's sales increased during that two year period ($10.1 million in 1995 versus $13.7 million in 1997). Design Fabricators was able to increase production and still lower their total mass emissions and their emissions per dollar of sales.

The reduction in HAP emissions was even greater. In 1995, approximately 20 tons of HAPs were emitted. By 1998, HAP emissions were almost eliminated, while production nearly doubled. The new coatings contain from 0.04 to 0.46 pound HAP per pound of solids. In addition, the glues, cleaning solvent, and stain base contain no HAPs.

Case Study No. 10 High-Solids Coatings
Ethan Allen
Beecher Falls, VT

Background

Ethan Allen's Beecher Falls facility manufactures several styles of high-quality bedroom and non-upholstered living room furniture. The plant has approximately 500 employees and is the main economic force in the Beecher Falls area. The facility is located in the northeastern-most point in Vermont, on the border with both New Hampshire and Canada.

This facility was one of the largest emitters of air pollutants in the State. Every year their reports under SARA Title III publicized their position as one of the State's "worst polluters." In an effort to improve their image within Vermont and to comply with both Vermont's air toxics rule and the Wood Furniture NESHAP, the Beecher Falls plant decided to make changes that would reduce their air emissions. This case study describes the conversion to high-solids sealers and topcoats and other pollution prevention efforts.

Manufacturing and Coating Operations

Previously, the Beecher Falls facility used traditional nitrocellulose-based sealer and lacquer that contained 18 percent and 20 percent solids, respectively. With the traditional coatings, one sealer and two lacquer applications were necessary to meet the company's quality standards. The coatings were applied using conventional spray guns. In an effort to reduce VOC emissions in the early 1990s, Beecher Falls switched to a higher-solids sealer and lacquer that contained approximately 24 percent and 28 percent solids, respectively. They encountered no problems upon switching to these higher solids coatings. Beecher Falls continued to investigate high-solids coatings in an effort to use an even higher-solids product to further reduce air emissions.

After careful evaluation, including pilot testing at the plant, they chose a 35 percent solids sealer and lacquer. The new system was fully operational by March 1995 and is currently in use. Because of the higher solids content of the new lacquer, the need for a second lacquer application was eliminated.

In the late 1980s, the Beecher Falls facility began using HVLP guns for some of their coating applications. The main motivation for this switch was the ergonomics of the lighter guns. However, in 1993 a study was done at the facility to investigate replacing all of the conventional guns with HVLP. On-line testing indicated an increased average transfer efficiency from 30 to 60 percent. This improved coverage reduced the amount of coating lost to overspray as well as the emissions from that overspray. The HVLP guns were implemented quickly.

Conversion to High-Solids Coatings
Through instituting a pollution prevention program, the Beecher Falls Division of Ethan Allen reduced VOC and HAP emissions by 28 and 55 percent, respectively, improved the work environment for its employees, and improved the efficiency of its production process. None of the changes made by Beecher Falls required a substantial capital investment, and each had a short payback period, making the changes economically attractive.

Beecher Falls was able to increase coating solids by working with their coating supplier and their equipment supplier to develop a satisfactory system. For example, the high-solids material could not be applied at room temperature with the HVLP spray guns. There were two feasible alternatives to make the HVLP guns work: using high pressure guns (1,500 to 3,000 psi) or heating the coating material to lower its viscosity. Beecher Falls chose to electrically heat the material in the coating supply line so that it reaches the gun at approximately 90°F. In addition, they modified the HVLP gun cap, nozzle, and tip to enable proper coating application. These modifications have not increased the pressure at the point of atomization beyond the 10 psi definition for HVLP.

The primary benefit to Beecher Falls has been that only one lacquer application is now needed to achieve adequate build. This eliminated the use of the second lacquer spray booth, and the two spray operators were transferred to other positions. At Beecher Falls, this newly available space was particularly valuable, and allowed for changes in the layout of the finishing department to make it more efficient. The elimination of one spray booth also reduced maintenance requirements, and subsequently the amount of solvent cleaner needed. The elimination of the second lacquer coat eliminated the need to sand the surface between coats (scuff sanding), again eliminating the need for two employees to perform this operation.

Reducing the lacquer application to one coat also produced savings on coating material, as well as reducing labor and air emissions. However, eliminating the second lacquer application requires stricter quality control and operator care when the single topcoat is applied. There is no longer a margin for error with the first coat that can be made up for with the second coat. Initially, repair requirements increased. The facility was able to overcome this problem with operator retraining and technique adjustments.

Beecher Falls believes that the new coatings and spray guns have improved worker health and safety conditions at their plant. There is less bounceback when the coatings are applied, reducing potential worker exposure. Lower bounceback also lowers overspray and reduces material use and air emissions further. After an initial period of adjustment, sealer and lacquer operators have expressed satisfaction with the new coatings and appreciate their improved work environment.

The sealer coat now has a better build, so when it is sanded there are less “cut throughs” (the operators do not sand completely through the sealer). This reduces the amount of touch-up required before lacquer application by approximately 30 percent over the previous sealer. The new lacquer covers defects better and reduces lacquer runs and sag, subsequently decreasing the need for final product repairs by approximately 50 percent. By switching to the high-solids sealer and lacquer, Beecher Falls believes that their final product quality has a fuller feel and better build. However, because the sealer coat has a higher build, it is more difficult to sand and requires an average of 30 percent more time per item. To maintain the same production level, two additional workers have been added to the sanding station. In addition, Beecher Falls replaced their block sanders with orbital sanders and now uses a different grit paper.

Other start-up problems the facility experienced with the new coatings were overcome. For instance, the high-solids sealer requires more time to dry, so Beecher Falls increased the airflow in the sealer flashoff area. The longer drying time and increased airflow increased the potential for dirt to contaminate the coating as it dried. Beecher Falls constructed a flashoff tunnel to help prevent the contamination. Layout changes to the finishing area were required to construct the tunnel.

Other Pollution Prevention and Recycling Efforts

HVLP guns

In the late 1980s, Beecher Falls began using HVLP guns for some of their coating applications because they are lighter and therefore ergonomically preferable when compared to conventional spray guns. Early in 1993, plant personnel investigated the possible benefits of replacing all of the remaining conventional spray guns with HVLP guns. Thorough testing on the actual finishing line for basecoat and stain application revealed (1) an average increase in transfer efficiency from 30 percent with conventional guns to 60 percent with HVLP guns, (2) a 39 percent reduction in the amount of finishing material used to coat the same item, and (3) a corresponding decrease in air emissions from the stations that had been using conventional spray guns.

At the time of the test, Beecher Falls still had 25 conventional spray guns. Approximately 53,000 gallons of finishing material was being sprayed from these 25 guns each year. A 39 percent reduction in material use translated into a savings of over 20,000 gallons of finishing material each year. Beecher Falls estimated that over $145,000 in finishing material purchase costs would be avoided each year if HVLP spray guns were used throughout the plant. The cost of each new HVLP spray gun was approximately $325, or a one-time $8,125 capital cost to produce a savings of over $145,000 each year thereafter. The payback period was less than 3 weeks. The conversion to HVLP spray guns was immediately approved and implemented. The only additional cost was training the operators on how to properly use the new spray equipment.

Waterborne basecoat

Beecher Falls has reformulated their color primer to a waterborne material. However, the waterborne material meets the facility's quality specifications only for opaque enamel applications. The black enamel used over the aqueous primer is still nitrocellulose-based due to space constraints that cannot support the increased drying time that would be required if aqueous paint were used. Only certain portions of some pieces are painted black, so the overall air emissions from the facility are not significantly affected by the switch to a waterborne primer because it is not used in large quantities.

Waterborne spray booth coating

The spray-on strippable spray booth coating used at Beecher Falls now is waterborne. With 23 spray booths in use, and stain booths coated every 6 weeks and the others coated 4 times each year on average, this coating change also helps to reduce air emissions.

Lacquer dust reclamation

The sealer and topcoat spray booths use metal filters. The filters are brushed at the end of each day to remove as much lacquer dust as possible. The lacquer dust is collected along with dust that has accumulated on the floor and placed in a 55-gallon drum. The dust is hand sifted through filters to remove impurities and then mixed with solvent to make a topcoat material that is used to coat the interior of drawers and backs of items. Beecher Falls uses approximately three 55-gallon drums of reclaimed lacquer dust each week, diverting it from disposal. Approximately one drum of unusable dust (the filter reject) requires disposal as a hazardous waste every month. Including the avoided cost of disposal and the 3 to 4 hours of labor spent on the reclamation effort each day, Beecher Falls estimates that it costs them approximately $4 per gallon to reclaim their lacquer dust; much less than the cost of purchasing new sealer or lacquer. The main drawback to the lacquer dust reclamation effort is that the recovered dust is potentially explosive. Extra care must be taken when handing and storing this material.

Costs

The costs of the conversion to high-solids sealer and lacquer are given below. The internal rate of return was 316 percent and the payback period was 4 months (based on a 5-year analysis, no depreciation of equipment).

Item	Savings or (Cost)
Labor	$175,000 per year
Materials	($42,000) per year
Capital Costs	($42,000)
Internal Rate of Return	316 percent
Net Present Value	$462,176
Payback Period	4 months

Labor
Elimination of two lacquer operators and two scuff sanders, reductions in pre- and post-lacquer touch up, and the addition of two sealer sanders combine for an estimated annual labor savings of approximately $175,000.

Material
The new high-solids coatings are twice as expensive as the original low-solids coatings on a per-gallon basis. However, because the solids content is higher, less material is needed to achieve the same dry mil thickness. In addition, one lacquer application was eliminated. Therefore, the total quantity of coating used is less. Beecher Falls estimated an increased material cost of approximately $42,000 per year. Beecher Falls has not determined the effect on electricity costs resulting from the in-line heaters and the increased airflow in the sealer flashoff area. However, due to the elimination of the second lacquer spray booth and its ventilation requirements, they do not believe there is a substantial increase.

Capital Costs
The cost of adding the in-line electrical heating systems and the flashoff tunnel was approximately $42,000.

Emissions
Air emissions of HAPs and VOCs from the Beecher Falls plant are almost exclusively from the finishing process. Prior to their pollution prevention efforts, the production of furniture involved the application of 70 different finishing materials in a total of nine separate applications. These were all low-solids, solvent-borne coatings. All finishing material is applied manually using a spray gun. In 1992, the plant reported total VOC emissions of 300 tons and HAP emissions of 95.6 tons to the U.S. Environmental Protection Agency.

The VOC and HAP emission reductions have been substantial because air emissions are directly related to the amount of coating used. Eliminating one lacquer application reduced material usage for lacquer coating by 46 percent. If the new coating formulations had the same VOC and HAP content as the old coatings, VOC and HAP emissions from the lacquer application step would be reduced by 46 percent. However, the coating formulations are not the same (42 percent fewer VOCs and 83 percent fewer HAPs), so reportable emissions from the lacquer application step have been reduced by more than 46 percent.

In 1995, production at Beecher Falls was 18.5 percent higher than in 1992, yet total VOC emissions were 257 tons per year and HAP emissions were 50.5 tons per year. Taking increased production into account, VOC and HAP reductions on a per part basis were 28 and 55 percent, respectively. No portion of the emission reduction was achieved through reformulating any coatings with acetone. Some stains and basecoats have been reformulated with acetone as the primary solvent; however, Ethan Allen has included acetone emissions in the 257 tons per year VOC figure. Acetone was removed from the U.S. EPA’s VOC list on June 16, 1995 and is not a listed HAP, but it remains as a listed hazardous air contaminant under Vermont regulations.

Acknowledgment
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Case Study No. 20 High-Solids Coatings and Waterborne Glue
Saloom Furniture
Winchendon, MA

Background

Saloom Furniture Company manufactures casual dining furniture and is based in Massachusetts. The company was started in 1982 by Peter Saloom and has evolved into a multi-million dollar company with more than 125 employees. The company expects to have more than $13 million in sales in 1998.

Saloom's basic business philosophy is to design, finish, market, and distribute. Customers can choose their own colors, fabrics, and tile designs, and Saloom will deliver the finished furniture in 3 to 4 weeks to the customer. Dining tables with ceramic tile inserts in wood frames were one of Saloom's first products, and this product has continued to be their best seller. They have added chairs and bar stools in the last few years to complement the tables and round out their product lines. They also coat a small volume of case pieces, such as buffets and hutches.

Saloom's manufacturing facility is located in Winchendon, MA, and is their only manufacturing facility. They consider themselves more of a finishing and final assembly operation type of furniture manufacturing facility. Of Saloom's 125 total employees, about 75 are directly associated with the manufacturing operations. Lloyd LeBlanc is the production manager and provided most of the information for this case study. The manufacturing facility works 1 shift, 5 days per week, with an occasional Saturday morning or extra hours on some days during their peak seasons. With their current production lines and floor space, they can increase the manufacturing staff by 40 percent before they would have to add a second shift. Saloom experienced 20 percent growth in 1998.

Winchendon is located in an area designated as attainment for ozone and the air quality monitors in the area show that the region attains the ozone standard. However, Massachusetts is within the political boundaries of the Ozone Transport Region.

Manufacturing and Coating Operations

Saloom receives most of their furniture components premilled and ready for final assembly and finishing. Most of the tables and chairs are made of solid maple or solid oak. The manufacturing area basically is divided into two lines. One line is used for assembling and finishing chairs and table base components. The second line is used to assemble and finish the wooden table tops or wooden frames. When Saloom added chairs to complement their table product lines, the facility's chemical usage more than doubled because of the additional surface area to be coated.

Chairs and Table Base Finishing Area
At the time of the visit to Saloom's facility, the production line was coating 230 pieces per day. Each coating is applied in a separate spray booth with HVLP spray guns. Pieces that will receive a stain first are sanded, and then toner is applied. Eight colors of toner currently are used, each with a dedicated line and gun. The toner is not wiped, and the pieces are left to dry about 30 minutes before receiving the next coating. The next spray booth is used to apply stain or whitewash. The stains are hand wiped and the pieces are inspected. The products receive a sealer, which is sanded by hand, and then receive a topcoat.

Some pieces receive only a sealer and topcoat if a natural appearance is desired. If the piece is to receive a color coat instead of a stain, it is sanded and finished with two coats of either white, black, or green paint. After the final coat, the pieces are inspected and sent on a conveyor to the packaging area.

Table Finishing Area
The table tops enter the finishing area from the sanding area via a conveyor and are taken to the toner booth where they are sprayed (except for the tile-top table frames, which do not receive toner). Dry time is approximately 30 minutes. The next step is the stain booth, where the stain is hand wiped and allowed to dry for 30 minutes. The table tops then go to the sealer booth, receive a sealer, and are allowed to dry for 1 hour. They are lightly sanded and sent to the clean room for the topcoat application. The tables are allowed to dry and are inspected. Casegood components also are finished in this area.

Gluing Operations
Saloom produces 40 to 45 tables per day and approximately half of those have in-laid ceramic tiles. The tiles are glued to the table tops and then silicone grout is applied around the tile edges. The grout is applied in an area enclosed with plastic curtains to prevent any particles from migrating to the finishing area where they can cause "fisheye" defects in the topcoat. Tables are packaged and shipped unassembled.

The adhesive currently used by Saloom in their manufacturing operations is "Titebond™ Solvent-Free Construction Adhesive" supplied by Franklin International, Inc. As suggested by the name, the material has a very-low VOC content: 0.043 lb/gal VOC.

Saloom started manufacturing plastic laminate table tops in 1997. The contact cement used on some of the plastic components had a high VOC and HAP content, but no other glues that they tested performed as well. They wanted to continue reducing air emissions and the product line was not selling well, so they discontinued the product line instead of furthering their marketing efforts. Some of their other table tops are solid Corian® or granite tops and have no associated coatings or emissions.

Cleaning Operations

The finishing line operators change the sealer and topcoat booth filters daily and clean the spray booths thoroughly once per week with solvent (e.g., booth stripper or lacquer thinner). Cardboard also is used to cover the floor during cleaning operations. The spray gun tips are cleaned daily with lacquer thinner and the coating lines are flushed once per week. Having dedicated lines for each color coat eliminates the need for flushing the lines during color changes.

Facility Experience with Coating and Glue Alternatives

Saloom looks for products that have low impact on the environment. They started manufacturing and finishing solid-wood top tables five years ago and have evaluated several different types of finishes. Saloom tests all finishes for usability and durability. They have their own internal tests based on their experience with customers. Over the past few years, Saloom has tested several waterborne finishes, but none of them have been able to meet their performance standards. Issues they experienced with the waterborne coatings tested included: longer dry times; rough finish due to grain raise; need for multiple coats to achieve the same finish resulting in higher material costs; and cloudy clearcoats. The dry times for the coatings tested were about four times as long as the coating they currently use. Because Saloom does not have the available floor space to handle that many additional in-process parts between spray booths, they will have to install some type of forced drying system if they begin using waterborne coatings.

Due to regulatory issues and a desire to keep their emissions under 50 tons per year, Saloom expects that they will be switching to some type of hybrid waterborne system in the next 2 to 4 years and will most likely install IR ovens to cure the coatings. They expect to convert to a waterborne topcoat first, and then eventually convert to a waterborne sealer and stain if they can find a high-quality product suited to their applications. They estimate that conversion to a waterborne topcoat will reduce their emissions by 20 percent.

Saloom also investigated high-solids, catalyzed coatings to replace solvent-borne nitrocellulose lacquers. One of the current nitrocellulose lacquers has a solids content of 35 percent by weight and a VOC content of 5.1 lb/gal. Saloom is using high-solids, catalyzed sealers and topcoats applied with HVLP spray guns. There are ten spray booths located in the facility and they usually are dedicated to a given type of coating applied to a specific product or group of products. However, because much of the coating operation involves physical moving of the parts into and out of the spray booth by the operator(s), there is a lot of flexibility as to how the booths can be used. Saloom is satisfied with the performance of the high-solids coatings.

Saloom invested in HVLP guns, but they feel that operator training is essential to achieving any savings in overspray. Initially, the operators wanted to apply the coatings the same way they did with airless equipment and turn up the pressure on the HVLP guns. To ensure operators were using the guns correctly, Saloom tried several types of process checks for the coating operations, such as (1) limiting the amount of coating operators could use per product; (2) flow checks on the lines; and (3) in-house enforcement actions. LeBlanc commented that they had a hard time getting operators to use the equipment correctly.

Other alternatives Saloom investigated include electrostatic spray and flatline finishing with UV-curable coatings. They found that they cannot use electrostatic application equipment for coating solid wood materials, and flatline and/or UV-curing equipment is cost prohibitive for the number of tables they are producing.

Saloom switched to waterborne adhesives four years ago for gluing ceramic tiles to table tops. Prior to the switch, they were using a high-emitting solvent-borne glue that was 12 percent VOCs per gallon. With the waterborne glue there are virtually no VOC or HAP emissions. One of the results of switching to the waterborne adhesives was having to allow for a slightly longer dry time. However, the operators find this glue easier to use, because the solvent-borne glue dried so quickly they could not apply it to the whole table top at once. The total amount of adhesive used remained the same with the switch to waterborne glue. The silicone grout used between the ceramic tiles has no VOCs. LeBlanc indicated Saloom had to make sure there were no negative interactions between the grout and the waterborne adhesive.

Sherwin Williams and C.E. Bradley are used exclusively as coating suppliers and provide excellent service and support. LeBlanc said he has tried other coating suppliers, but did not experience the same level of customer service. Service is important to Saloom because of all the variables that can affect the final finish: wood, climate, application equipment, and application technique.

Costs
The Saloom representatives were not able to provide any cost information concerning the previous operational changes involving coatings and adhesives; however, they are anticipating the process change to the hybrid system to increase their operating costs by 5 to 10 percent.

Emissions
Saloom’s VOC emissions in 1997 were 23.8 tons per year and they used approximately 10,000 gallons of coatings and solvents. Saloom’s current permit allows 23 tons of VOC emissions per year, compared to a 12 ton per year limit in 1992. LeBlanc stated that Saloom has requested a higher VOC limit (49 tons per year) to accommodate the growth that they have experienced, and the expected growth in the next 5 years. The State permit authority is in the final stages of approving the higher limit. Saloom also is subject to the Wood Furniture NESHAP.

Summary
Saloom has a good history of being proactive in their efforts to reduce and minimize VOC emissions, and is utilizing work practices, operator training programs, and

housekeeping measures to minimize VOC and HAP emissions. They have reduced solvent use for gun cleaning and have dedicated color lines and pots at the finishing operations. Saloom has developed an internal operator training manual for finishers which has resulted in less rework and less material (coating and cleanup solvent) usage.

Saloom wants to develop a hybrid waterborne coating system utilizing a waterborne topcoat. They hope to start using waterborne stain(s) and sealer(s) eventually, but are concerned about the grain raise issue with current products on the market. These changes could reduce the VOC emissions another 20 percent.

Saloom anticipates being able to double their current production without doubling their VOC emissions. They believe that the coating suppliers will make improvements in their coatings before Saloom gets close to the new (proposed) limit of 49 tons of VOCs per year and they will find a waterborne finishing system that meets their needs.

Case Study No. 25   High-Solids Coatings
Westwood Custom Cabinetry
Salem, OR

Background

Westwood Custom Cabinetry began coating cabinets in 1971 and was bought in February 1998 by Elkay. Their new sister plant in Minnesota, Medallion Cabinets, manufactures the same products. There are 83 manufacturing employees at the Salem facility, including 12 to 13 finishing employees, who work Monday through Friday on an 8-hour shift. Westwood converted to high-solids, low-HAP coatings to comply with the Wood Furniture NESHAP.

Manufacturing and Coating Operations

Westwood receives most of their components premilled. A few cabinet components, such as box and drawer parts, are received prefinished. The types of wood coated are oak, maple, hickory, and cherry. They will eventually coat pine as well.

The manufacturing section of the facility is divided into two areas. One area is used for assembling prefinished box and drawer parts manufactured of particleboard and paper laminate or maple veneer. The second area includes the finish room, where cabinet doors and molding are finished and assembled. At the time of the visit to the facility (August 1998), Westwood was beginning to switch to a new product line and had implemented a plan to minimize leftover coatings and components from the old product line. The new product line is finished with the low-HAP coating system.

The facility has one coating line that moves at approximately 26 feet per minute. The parts move on a conveyor system that has 100 trays with paper honeycomb-type disposable liners. These liners are replaced every 3 to 4 months, depending on the facility's production volume. The parts are coated in three steps. The first step in the coating process is a spray booth used to apply stain to the parts. Some stains are wiped after they are sprayed on the piece, and some are not. The parts then pass through a flashoff oven, which uses heat from the other ovens in the line. The parts may then be touched up by hand using thinning solvent or additional stain if the color is uneven, particularly for darker stain colors. A catalyzed sealer is then applied, the parts pass through another oven for drying, and the parts are sanded by hand. Finally, a catalyzed topcoat is applied, and the parts pass through the final drying oven. All coatings are applied using HVLP guns manufactured by Kremlin.

One finishing cycle takes approximately 45 minutes to complete; cabinet doors pass through the line twice so both the front and back are finished. When the facility begins coating the new product line, some of the colors will require a dye before the stain is applied.

The stains are received in 55-gallon drums; the sealer and topcoat are received in large stainless steel totes. The stains are pumped from the drums directly to color-dedicated spray guns at the coating line. Therefore, a color change does not require the lines and guns to be flushed with solvent. The sealer and coating are catalyzed 5 gallons at a time and taken in buckets to the finishing line. At the end of the shift, any unused coating is put back into the tote. The totes are returned to the coating supplier and reused. The empty stain barrels are given away or crushed as scrap.

Cleaning Operations
The facility uses thinner purchased from their coating supplier, Akzo, to clean the spray guns that apply the catalyzed sealer and topcoat. The guns used to apply the stains are cleaned less often, since each color has a dedicated line and gun. The thinner contains less than 10 percent HAPs, per the Wood Furniture NESHAP requirements. They spray the thinner directly into the spray booths, and estimate approximately 3 gallons of cleaning solvent are used per day. The spray booth filters are changed every one to two days. Both the spray booth filters and tray liners are landfilled. The facility produces no hazardous waste.

Conversion to High-Solids/Low-HAP Coatings
Westwood has transitioned from a toluene- and xylene-based catalyzed conversion varnish system to low-HAP, catalyzed sealers and topcoats and low-HAP stains. Westwood experimented with some waterborne coatings, but experienced problems with dry time, clarity, and grain raise. Cost also was an issue in choosing not to switch to waterborne coatings (equipment changes would have been necessary). They tested a total of about 150 gallons of waterborne sealer and topcoat, as well as a small amount of waterborne stain.

The switch to low-HAP coatings required no changes to the configuration of the coating line and no additional operator training. The new HVLP guns did require some operator training. The operators received instruction in the technical aspects of the new product line's colors and the additional dye that some pieces will receive prior to the stain. Some training will be provided by the coating supplier's local representative, who visits the facility weekly.

Costs
All coatings are applied using HVLP guns manufactured by Kremlin. These guns were purchased to replace older HVLP guns and air-assisted airless guns. New guns and lines were purchased and installed at a cost of approximately $80,000. The old HVLP guns had been adjusted to use a higher pressure and larger tips so they could apply sufficient coating for the speed of the line. Therefore, they were not achieving the high transfer efficiency typical of HVLP guns. They also were heavy and cumbersome for the operators to use. The newer guns are lighter and supply a sufficient amount of coating to accommodate the speed of the line. The new sealer and topcoat cost about $1.30 more per gallon, but with the new HVLP guns and the higher solids content,

Westwood will be applying less coating per piece. Therefore, they are likely to experience a cost savings.

Emissions

Westwood's permit limits them to 276 tons of VOCs per year. They also are subject to the Wood Furniture NESHAP. All their new coatings have HAP contents below the NESHAP limits. According to data supplied by the facility, in 1997, the average emissions were 2.51 pounds of VOCs and 1.28 pounds of HAPs per cabinet. The facility began spraying the new low-VOC/HAP coatings in 1998, and expected a decrease in emissions as well as increased transfer efficiency due to the new HVLP guns. For the first half of 1998, facility data indicated that VOC emissions were 1.74 pounds per cabinet and HAP emissions were 0.86 pound per cabinet.